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RELATIONSHIP BETWEEN STATIC AND DYNAMIC STEREO ACUITY[1]

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Equidistance settings were obtained from 50 Os with a Howard-Dolman type apparatus which was either stationary or rotating about O at angular speeds of 60 to 180 deg/sec. The correlation between the settings decreased as the disparity of the speeds being compared increased, and there was a sharp drop in correlation between the stationary condition and any speed. At any speed of rotation, there was an increase in the variability of the settings as viewing time decreased and a sharp increase below .3 sec. A positive localization error was made by 24 Os and a negative error was made by 26 Os. There appears to be a relationship between positive errors and exophoria and between negative errors and esophoria.

Considerable attention has been devoted to the study of "dynamic visual acuity," the ability of *O* to discriminate an object when there is relative movement between *O* and object, and to the question of the relationship between dynamic and static acuity (Weissman & Freeburne, 1965). There has been much less attention to what may be called dynamic stereo acuity and apparently none to the relationship between it and static stereo acuity.

Lit (1966), Lit and Hamm (1966) have carried out long series of studies, however, which bear on the problem. Using an apparatus that presents a stationary rod and a comparison rod which oscillates in a frontoparallel plane, they have provided considerable information on depth-discrimination thresholds and on apparent equidistant settings of the two rods as a function of such variables as speed of oscillation and level of illumination.

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But Lit's studies have typically used only two or three *O*s, making it somewhat difficult to assess the relation between the thresholds for stationary rods and those when movement is present. Further, Lit has repeatedly found a dichotomy in the direction of constant error in his small samples that has been hard to explain. For these reasons, a study involving a large number of *O*s was desirable.

Experiment I

Apparatus and method.—The apparatus was essentially a Howard-Dolman device which could be rotated about *O*'s head. Two steel rods, painted flat black, were suspended from a wooden arm. The right rod was fixed in position at a distance of 137 cm. from *O*; the left rod could be moved nearer or farther from him. The rods were .25 cm. in diameter (.1° visual angle) and 7.5 cm. apart (3° visual angle). The speed of rotation was controlled by a constant speed motor and a series of friction spindles of varying diameter. The direction of rotation was always from *O*'s left to his right. Four speeds of rotation were used: 60, 90, 120, and 180 deg/sec.

The *O* sat in a booth with his eyes under the center of rotation of the arm and looked through a long, narrow slit in the curved front of the booth. The slit provided a field of view of 110° maximum width and 9.5° high. The background visible through the slit was a curved screen painted flat white

and illuminated to 15 ftl. The inside front of the booth was also flat white and illuminated to 5 ftl.

Thresholds were measured with the method of constant stimuli. After each setting of the variable rod, *O* was given one presentation and asked to judge whether the right rod was closer or farther than the left one; no judgments of equality were permitted. A frequency of seeing curve was plotted on a cumulative normal frequency distribution and the 50% point taken as the threshold. Each threshold was based on about 20–25 judgments. Settings of the variable rod were made behind the viewing booth during measurements of dynamic acuity; during measurements of static acuity, an auxiliary shutter was used to screen the adjustments. The *O* did not know which rod was being varied.

Procedure and Os.—The viewing time was kept constant for the moving targets. Since the maximum width of the viewing slit was 110°, the maximum viewing time for the fastest speed of rotation, 180 deg/sec, was .61 sec. This was, therefore, the viewing time which was set up for the other speeds by decreasing the width of the viewing slit as the speed decreased. The viewing time for the stationary thresholds, however, was maintained manually at about 1 sec. Thresholds under the various conditions were measured for 50 *O*s, both civilian and military, on the Submarine Base. Each *O* participated only once. During a session, the five conditions were presented in a different random order to each *O*.

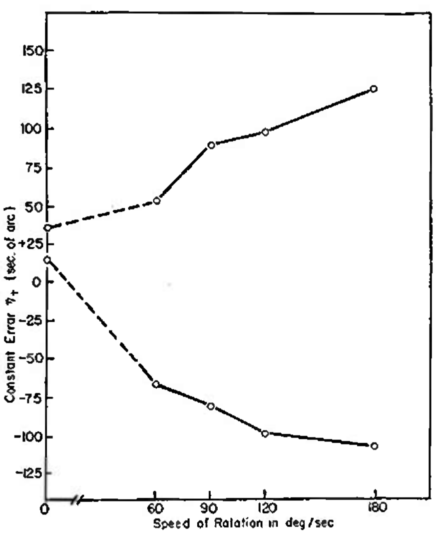

FIG. 1. Average constant error as a function of angular speed of rotation for 24 *O*s making increasingly positive errors and 26 *O*s making increasingly negative errors. (Viewing time was .61 sec. for the moving targets and about 1 sec. for the stationary targets.)

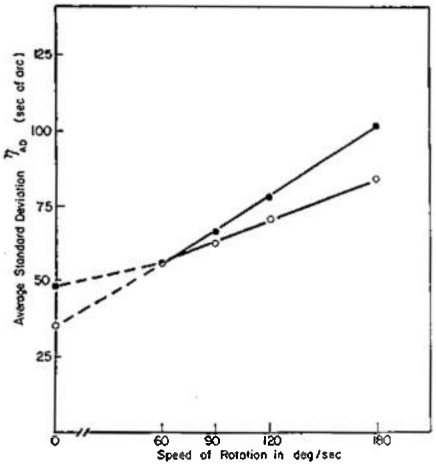

FIG. 2. Average standard deviations of settings as a function of angular speed of rotation for the positive constant errors (open circles) and negative constant errors (filled circles).

Results.—The dichotomy in the direction of localization error or stereo threshold, which has invariably appeared in Lit's (1960) data, was immediately apparent in this experiment. As the speed of rotation increased, 24 of the 50 *O*s judged the rods to be equidistant when the variable was increasingly farther away (positive error) than the comparison rod, while 26 judged them to be equidistant when the variable was increasingly closer (negative error). The average constant error as a function of increasing speed is shown for the two groups in Fig. 1. The range is somewhat smaller for the "far" than for the "near" settings.

The average standard deviations for these settings are shown in Fig. 2 for both groups. They are also consist-

TABLE 1

Matrix of Correlations of Stereo Thresholds

	60	90	120	180
0	.33*	.32*	.23	.11
60		.94**	.92**	.75**
90			.87**	.77**
120				.84**

Note.—In deg/sec.
* $p < .05$.
** $p < .01$.

ently smaller for the "far" settings. As speed increases, variability increases at approximately twice the rate as does the constant error.

The correlations between the settings under the various conditions for the 50 *O*s are given in Table 1. As expected, the correlation between their settings decreases as the disparity between the speeds being compared increases. But the most marked feature of these results is the sharp drop in the correlations between the stationary and moving settings. The correlations between any two rates of movement are significant at the .05 level, but only two correlations involving the stationary condition are significant at the .05 level. The correlations were computed taking into account the direction of the constant error. Of the 50 *O*s, 19 showed a crossover, that is, a constant error in one direction for the stationary targets and an error in the opposite direction for the moving targets. An extreme set of data, for an *O* with poor stereo acuity is shown in Fig. 3.

To see if *O*'s variability might be a more sensitive indicator of his performance than the threshold (Siegel & Dimmick, 1962) the standard deviations were also correlated. Table 2 gives the correlations between the standard deviations under the various conditions. Except for the correlations involving the static condition, they are generally appreciably lower

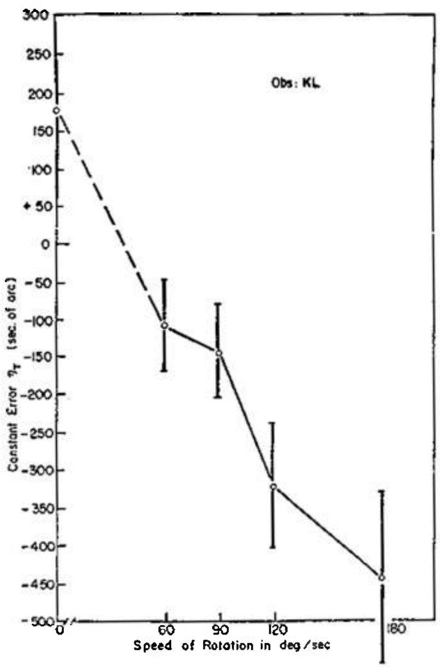

Fig. 3. Constant error as a function of angular speed of rotation for *O* KL. (Vertical bars indicate the standard deviations. Although extremely large deviations of an *O* with poor stereo acuity, they illustrate the not uncommon crossover from positive to negative constant errors when movement is introduced.)

and more erratic than the correlations between the thresholds.

In an attempt to explain the dichotomy of constant errors, all *O*s were tested for eye dominance with the method devised by Miles (1929). The results in Table 3 show there is no relationship between eye dominance and

TABLE 2

Matrix of Correlations of Standard Deviations of the Stereo Thresholds

	60	90	120	180
0	.32	.36	.27	.19
60		.25	.26	.31
90			.23	.47
120				.32

Note.—In deg/sec.

TABLE 3

RELATION OF EYE DOMINANCE TO THE DIRECTION OF CONSTANT ERROR

	Left Eye Dominant	Right Eye Dominant
Variable Rod Set Farther	10	16
Variable Rod Set Nearer	10	14

direction of constant error. There were also no changes in the thresholds of two *O*s who were retested (*a*) with the right rod as the variable and (*b*) with movement from right to left.

Next *O*s were tested for lateral phorias by the Maddox rod test with the test light also placed at a distance of 137 cm. from *O*.[8] Since most of the *O*s were sailors, arrangements could not be made to test all of them. Of the 50 *O*s, only 22 were tested. Of these, 7 were found to have less than one diopter of lateral phoria and were ignored. The breakdown for the remaining *O*s is shown in Table 4. Of the 7 *O*s exhibiting more than one diopter of exophoria, all but 1 set the variable rod increasingly farther than the comparison with increasing speed; of the 8 *O*s exhibiting esophoria, all but 1 set the variable rod increasingly nearer than the comparison.

EXPERIMENT II

A second experiment was carried out to study the effects of both viewing time and tracking distance on constant error. One aim was to see if the increases in localization error and variability were the result of the reductions in the width of the viewing slit by which a constant viewing time was maintained for the various speeds. This could be determined owing to the fact that there would be several speeds at different viewing times with the same size viewing slit.

Procedure and observers.—Three *O*s were selected who showed positive errors in the first experiment, and one who showed negative errors. At each of the four speeds of rotation, their thresholds were measured for five viewing times from .2 to .6 sec. One speed was tested during each session, and the various viewing times were presented once in a different random order to each *O*; the various speeds were also presented in a different random order to each *O*. There were three sessions per condition for each *O*.

Results.—Results are presented only for the three *O*s with the positive errors. The average constant errors are shown in Fig. 4; the average standard deviations are shown in Fig. 5. (The fourth *O*, tested merely for comparison, gave comparable results with, of course, a negative error.) Figure 4 shows that the constant error increases with decreasing viewing time. Figure 5 shows that variability again increases with decreasing viewing time, and also

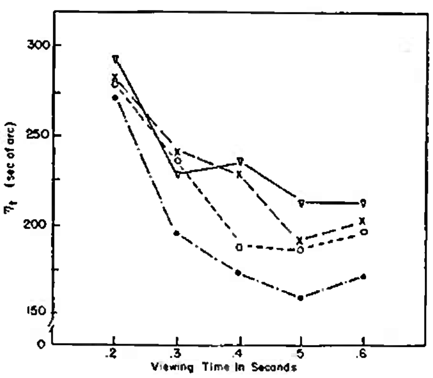

FIG. 4. Average constant error as a function of viewing time for angular speeds of rotation of 60 (●), 90 (○), 120 (×), and 180 (▽) deg/sec.

[8] The authors are indebted to Ira Schwartz for the suggestion and to P. R. Kent, MSC, USN, for measuring the phorias.

TABLE 4

RELATION BETWEEN LATERAL PHORIA AND DIRECTION OF CONSTANT ERROR

	Exophoria	Esophoria
Variable Rod Set Farther	6	1
Variable Rod Set Nearer	1	7

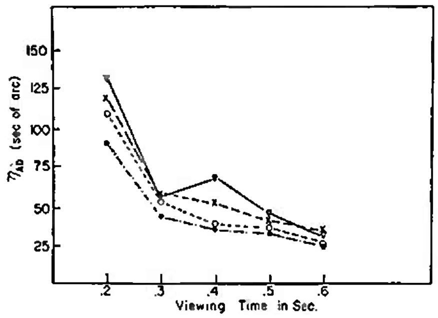

FIG. 5. Average standard deviations of settings as a function of viewing time for angular speeds of rotation of 60 (●), 90 (○), 120 (×), and 180 (▽) deg/sec.

with speed at any given viewing time. Of special interest, however, is the relatively large increase at .2 sec. for all speeds.

An interesting comparison can be made between the results in these two experiments. In Exp. I, when the task was made more difficult by increasing the speeds of rotation, the variability increased at about only twice the rate that the constant error did. In the second experiment, when the difficulty of the task was increased by decreasing the viewing time, variability increased at between three and four times the rate that the constant error did. If the ratios of the variability to the thresholds in Exp. II are plotted for each speed (not shown), they all increase almost identically as viewing time decreases. This indicates that the variability at short exposure times is increasing faster than the magnitude of the error irrespective of speed. At any given viewing time, however, the ratios are virtually constant as a function of speed—as they were in the first experiment.

Discussion

There is great similarity between these results and those obtained by Lit with a much different method. Both show the increase in error and variability with increasing speed, the split into two directions of the errors, and a greater negative than positive error.

These similarities make it unlikely that the present results are due to variations in tracking distance rather than speed. If this were true, those conditions in Exp. II which have the same tracking distance should show the same results. There are several sets of conditions which share approximately the same tracking distance, for example, 180 deg/sec at .2 sec., 120 deg/sec at .3 sec., 90 deg/sec at .4 sec., and 60 deg/sec at .6 sec. The variations in thresholds and more clearly, in the standard deviations, which rise from 35 to 131 sec. of arc, leave no doubt that constant tracking distance does not produce constant results.

The close correspondence of the curves for the various speeds in Fig. 5, on the other hand, indicates that viewing time is a most important factor. Between .3 and .2 sec., there is a sharp rise in the variability of the settings. This is much larger than the rise in variability as a function of speed at any given viewing time. These results appear to indicate that between .2 and .3 sec. are needed to start tracking. This estimate conforms well with the determinations of the response time of the eye to the presentation of a stimulus (Westheimer, 1954). Given that much time, *O*s form a judgment of the relative distance of the rods with rather stable precision irrespective of speed or accompanying localization error.

The increase in size of the error with increasing speed is a very interesting phenomenon. Conceivably, with increasing speed, there might simply have been an increase in the variability of the thresholds, without a change in the point of subjective equality. But, as Galanter (1962) has pointed out, when discrimination becomes poorer, there is an increase in any constant error which is present.

The relation between lateral phoria and constant error closely resembles the relation between phoria and fixation disparity reported by Ogle (1950). Here, too, the direction of the fixation disparity is the same as that of the phoria in a majority, but not all, of the *O*s. In both sets of

data, there is also a low correlation between size of the phoria and magnitude of the error. The present results have shown, moreover, that many *O*s exhibit opposite constant errors for stationary and moving thresholds, and others cross over at different points. Presumably there are many other factors involved in this phenomenon, such as individual differences in torsional effects and convergence which must be taken into account.

Finally, the low correlations between static and dynamic stereo-acuity indicate that when stereo-acuity for moving targets is an important consideration, a conventional test for static stereo-acuity may not be adequate. As noted above, Weissman and Freeburne have also found low correlations between static and dynamic acuity at high speeds. These findings suggest that we may ask whether there is ever a high correlation between the static and dynamic states of any visual function.

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